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FIRST DENSITY MEASUREMENTS WITH MICROWAVE REFLECTOMETRY ON ASDEX UPGRADE

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A broadband one-antenna reflectometry system is under developement for the ASDEX Upgrade tokamak, to probe the plasma from the edge until the bulk region. Presently two K-band (O-mode) channels, installed respectively at the high and low sides, are in operation (broadband and fixed frequency), providing the first direct simultaneous measurements of the plasma density at both sides ($n_e \approx 0.3$ to $0.8 \times 10^{19}\ m^{-3}$).

The modifications of the inner and outer density profile due to radial displacements of the plasma column are shown. In H-mode regimes, the changes of the edge density gradients and of the level of fluctuations were studied.

I. The reflectometry system for ASDEX Upgrade

The reflectometry system for ASDEX Upgrade will operate in the frequency range 16 to 110 GHz probing the plasma from $n_e \simeq 0$ (X mode) up to $n_e \approx 15 \times 10^{19}\ m^{-3}$ (O-mode) [1]. The diagnostic includes thirteen channels with in-vessel antennae installed both at the high and low field sides. Each antenna is used both for emission and for reception thus reducing the access to the machine. Several features of the diagnostic guarantee the quality of the detected signals. The emission and detection sections are placed close to the tokamak avoiding the use of oversized waveguides that may cause spurious reflections due to higher mode propagation. The signals are generated by units that include solid state oscillators (HTO), active frequency multipliers and special drivers for fast sweep operation, $\geq 10\mu s$, (needed to minimize the effect of fluctuations in profile measurements). Up to one thousand profiles can be measured per shot, with a minimum repetition interval of $\simeq 20\mu s$. The system is totally remotely controlled through optical fiber links. Data acquisition uses a dedicated system with high computing power and data compression facilities; on-line profile evaluation is also being implemented.

II - Experimental results

Results refer to broadband swept experiments performed with $\Delta t_s = 100\mu s$ (presently the system can operate down to $10\mu s$ sweeping time). Broadband reflectometry is the only technique that fully exploits the unique capability of reflectometry to probe an "infinite" number of plasma layers with each channel. The differential phase shift $(d\varphi/df)_F$ that the waves F undergo in the plasma, which is the relevant quantity for profile evaluation, is continuously measured. Due to the detailed measurement, perturbations of the differential phase shift due to plasma fluctuations can in most cases be easily identified, enabling to obtain the plasma profile by simple filtering the disturbed characteristic [2]. From the measured differential phase shift curve it is also possible to infer the density regions where fluctuations exist, as shown in section 2.

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1. Plasma radial displacements

In **Fig. 1** it is presented the spectra of the raw data signals obtained at different time instants of discharge 3068, where the plasma was horizontally displaced up to 4cm. An increase of the frequency of the main peak is observed at the low field side and a decrease is seen at the high field side. Results indicate respectively a displacement of the probed plasma region away from the outer antenna and towards the inner antenna. The measured frequency shifts agree with the evolution of the distance between the antennae and the plasma outer radius $(R_a - R_{out})$ and inner radius $(R_{in} - R_a)$, as can be seen in **Fig. 2.**

The observed variations should be mainly due to changes of the vacuum distance where the probing microwaves have propagate. The evaluated profiles, however, show significant asymmetries in the outer and inner plasma. In **Fig.3** it is depicted the profiles corresponding to a radial shift of 2cm of the plasma column. The fitting of the experimental $n_e(r_i)$ points, shown in the figures, is an "average profile" that was obtained from the fitting of the measured phase shift characteristic $\varphi_i(F_i)$. The average curve $\varphi(f)$ was then processed to obtain the "average profile". Results reveal a global displacement of the profile of ~2cm at the low field side and a change in the plasma edge shape at the high field side.

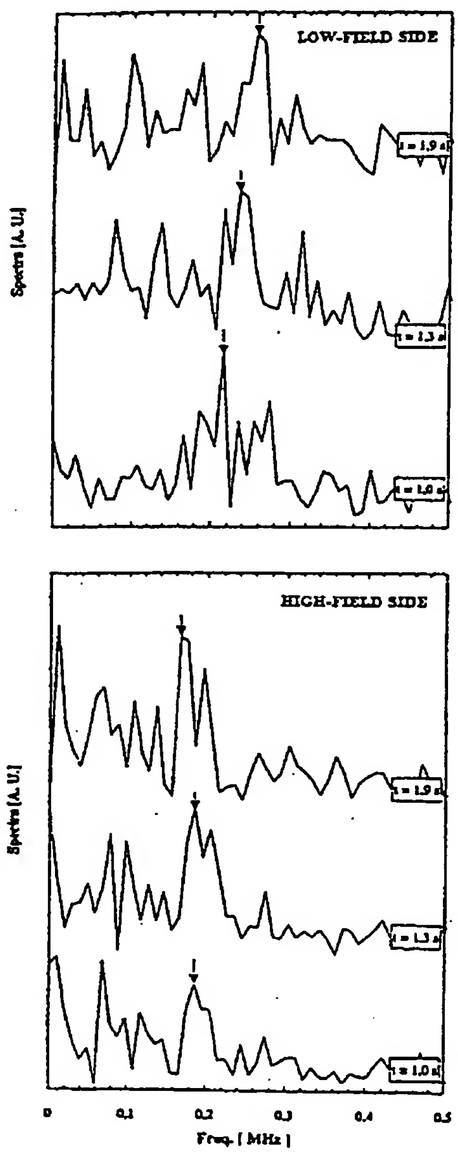

Fig 1

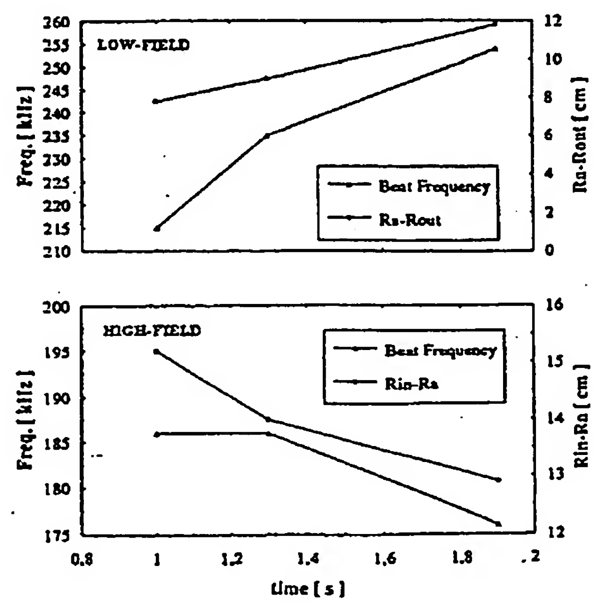

Fig 2

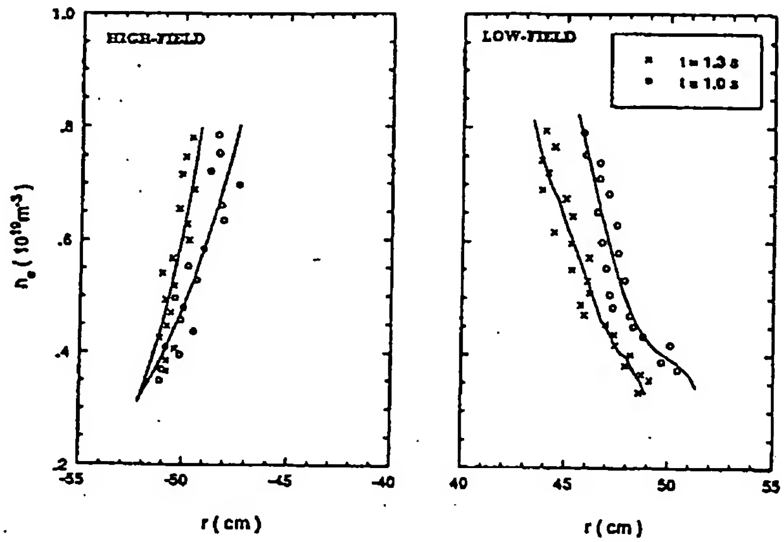

Fig. 3

2. H mode regimes

In Fig. 4 it is presented the phase shift derivatives obtained in 100 μs and spaced by 10ms, during the ICRF heated plasma of discharge 2325. The L to H transition ocurred at t $\sim$ 1.641s. Before the transition ($\Delta t = -1ms$) the phase perturbations are observed to increase at both channels. (A similar behaviour has been observed in ASDEX with H modes achieved with neutral beam injection). Following the transition ($\Delta t = +9ms$) the perturbations decrease to levels below those observed at the L phase ($\Delta t = -11ms$). In the ELMy phase two samples are shown respectively before an ELM ($\Delta t = +259ms$) and during an ELM ($\Delta t = +269ms$). The level of fluctuations increase at both sides during the ELM, specially at the peripherie, and the edge profile flattens, as can be concluded from the corresponding profiles depicted in Fig. 5.

Results presented above show that the changes in density profile and fluctuations occur both at the high and low field sides (the peaking of the profile is also observed at the L to H transition in both sides). However, other measurements where samples were obtained closer ($\Delta t \leq 2ms$) to the L to H transition suggest that a delay exists between outer and inner density changes. In H modes achieved under Ohmic conditions the above density signatures of the H regimes were also found.

III - Concluding remarks

A reflectometry system is being installed in the ASDEX Upgrade tokamak. Presently two channels probing the edge plasma at the high and low field sides are in operation (broadband and fixed frequency). Results are presented showing that radial displacements of the plasma column can cause different modifications of the outer and inner plasma density profiles. In H mode regimes under ohmic conditions and with ICRF heating, the peaking (flatenning) of the profile and the decrease (increase) of the level of fluctuations at the L to H transition (during an ELM) were observed at both sides.

Results showed the great potentialities of broadband reflectometry namely to study the inner and outer asymmetries of the density profile. The diagnostic capability shall be greatly increased with the installation (by September 1993) of three channels probing inner plasma layers (O-mode) and the edge region (X mode). In particular, the spacial resolution of the measurements at the edge shall be improved with X mode operation.

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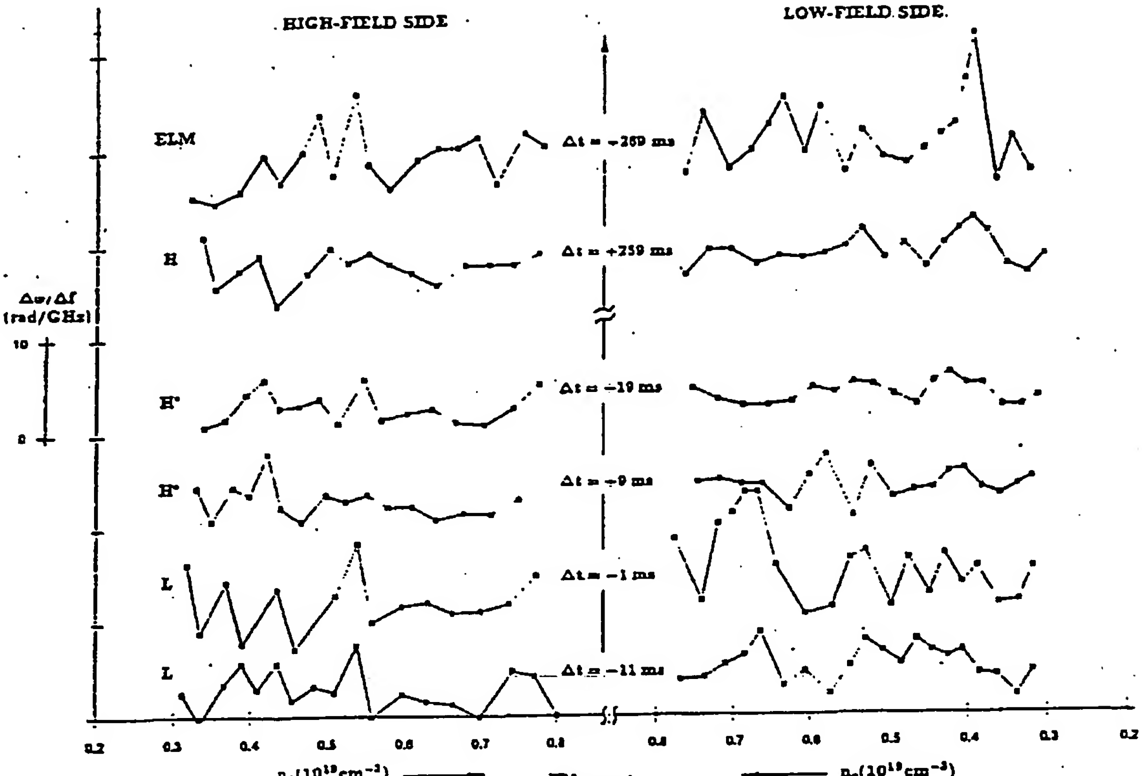

Fig. 4

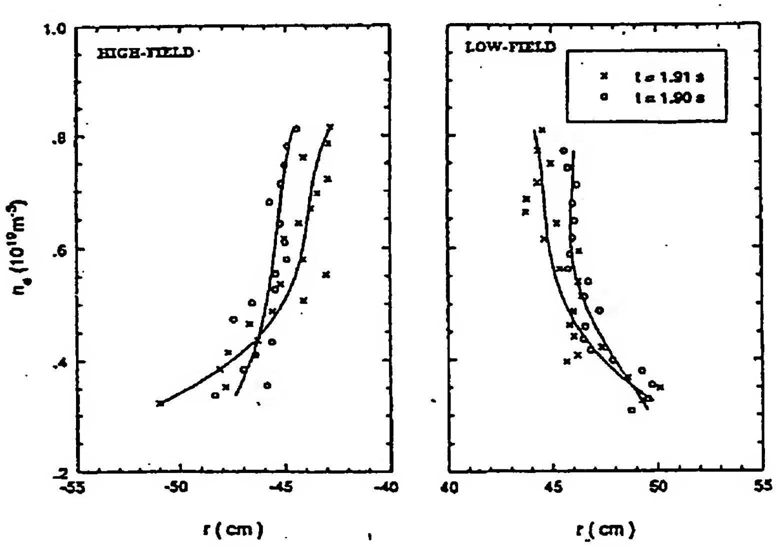

Fig. 5

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[1] A. Silva, L. Cupido, M.E. Manso, F. Serra, P. Varela et al., "17^{th} Symposium on Fusion Technology", Rome, 1992.

[2] M.E. Manso, Proc. IV Workshop on Magnetic Confinement Fusion: Diagnostics for Tokamaks and Stellarators, Santander, 1992.

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